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***Salibu* rice cultivation in Indonesia's lowlands: A review of agronomic innovations and sustainability pathways**

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ABSTRACT

The *Salibu* system is an indigenous rice cultivation technique developed by farmers in West Sumatra, Indonesia, which allows multiple harvests from a single planting through the regeneration of tillers from post-harvest rice stubble. Despite its promising potential to enhance rice productivity and sustainability, its adoption remains limited, highlighting the need for a comprehensive review of its principles, applications, and constraints. The structure of this review comprises seven main sections, including an overview of Indonesia's lowland rice agroecosystems, the *Salibu* system, innovations, productivity impacts, adoption strategies, challenges, and future development recommendations. This review synthesizes agronomic principles, regional applications, and the sustainability potential of the *Salibu* system within Indonesia's lowland rice agroecosystems, and key innovations such as precision stem cutting, alternate wetting and drying (AWD) irrigation, and the use of biofertilisers. Drawing from scientific literature, field reports, and local practices, this article identifies that these innovations can improve regenerative growth, yield stability, and environmental efficiency. However, broader implementation faces challenges, including incompatible rice varieties, variable soil conditions, limited farmer knowledge, and inadequate institutional support. The findings suggest that successful adoption depends on targeted farmer training, participatory extension models, and supportive agricultural policies. In conclusion, the *Salibu* system offers strong potential to increase rice yields, reduce environmental impacts, and support smallholder livelihoods. Coordinated efforts in research, policy, and on-farm implementation are essential to scale its impact and integrate it into national climate-resilient food strategies.

Key words: Agricultural innovation, lowland, rice, *Salibu* system, sustainable intensification

INTRODUCTION

Rice (*Oryza sativa* L.) is the primary staple food for over 90% of Indonesians, with more than 80% of national production sourced from lowland rice fields due to their stable agro-ecological conditions and well-managed irrigation (Sembiring *et al*., 2020). However, despite increased use of modern inputs like fertilisers and high-yielding varieties, productivity has stagnated over the past two decades. This is largely due to declining soil fertility, disease-prone varieties, and inefficient water and fertiliser use (Wassmann *et al*., 2009). Soil degradation, water stress, and climate-induced disruptions such as erratic rainfall and prolonged droughts have further challenged the resilience of conventional rice cultivation (Lal, 2015; Dou *et al*., 2016).

In response to these challenges, the *Salibu* system has emerged as a promising indigenous innovation rooted in West Sumatra's farming traditions. It leverages the rice plant's natural ability to regenerate tillers from post-harvest stubble, enabling multiple harvests without reseeding or full land

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preparation (Abdulrachman *et al*., 2015). When properly managed, *Salibu* systems can achieve yields comparable to initial plantings while reducing seed, labour, water, and energy inputs (Oda *et al*., 2020; Shiraki *et al*., 2020). These features make the *Salibu* approach particularly relevant for sustainable intensification in the face of climate variability, declining input efficiency, and limited land availability.

Over the past decade, growing interest in *Salibu* cultivation among researchers, extension agencies, and policymakers has led to studies on its agronomic performance, cost-effectiveness, and adaptability in rainfed, irrigated, and tidal lowlands (Fitri *et al*., 2019). Innovations such as precision stem cutting, AWD irrigation, the use of early-maturing varieties, and the application of biofertilisers have further enhanced the system's effectiveness and ecological value (Bouman *et al*., 2007; Doni *et al*., 2018). Despite its potential, *Salibu* adoption remains uneven due to knowledge gaps, varietal mismatches, technical constraints, and limited institutional support (Mayly and Syafri, 2018; Yamaoka *et al*., 2023).

The objective of writing this article is to synthesise current knowledge and field experiences related to *Salibu* rice cultivation in Indonesia's lowlands, with a focus on its agronomic innovations and sustainability potential. The review aims to highlight the key principles and regenerative mechanisms underlying the *Salibu* system, assess its regional implementation and the challenges associated with its adoption, and explore strategic opportunities for integrating *Salibu* into national sustainable intensification frameworks.

This review focuses on *Salibu* practices in Indonesia's lowland rice ecosystems, including irrigated, rainfed, and tidal fields. It excludes ratooning systems in upland or highland areas and hybrid or mechanised rice systems in non-tropical regions, drawing on literature from 2000 to 2024. The structure of this review comprises seven main sections, including an overview of lowland rice agroecosystems in Indonesia, detailed analysis of the *Salibu* system, innovation in the *Salibu* system for lowland rice, impact of the *Salibu* system on lowland rice productivity, adoption and dissemination of the *Salibu* system in lowland rice, challenges and limitation of the *Salibu* system, and future development directions and recommendations.

Lowland Rice Agroecosystems in Indonesia

The lowland rice agroecosystem refers to rice cultivation on land situated below 400 m above sea level, characterized by a stable water supply and seasonal flooding (Dobermann and Fairhurst, 2000). These areas, predominantly comprising clay or silty clay soils, are ideal for irrigated rice due to their water retention capacity and the formation of an impermeable plow pan (Fageria *et al*., 2011). Such soil properties facilitate higher yields and improved water productivity, particularly under prolonged waterlogged conditions (Dou *et al*., 2016). Indonesia's rice-growing areas span irrigated, rainfed, tidal, and swampy lowlands, totalling 8.1 million hectares.

The *Salibu* system, which enables regrowth from harvested stems, relies on precise harvest timing, accurate stem cutting, and careful management of water, fertilisers, and suitable rice varieties. However, productivity in lowland rice systems is often limited by cultivars that struggle with abiotic stresses such as drought, flooding, and temperature fluctuations. Long-duration varieties tend to underperform under erratic weather or delayed planting. In contrast, local genotypes like *Sironda Putiah* and varieties with the *Sub1* gene offer greater resilience (Wassmann *et al*., 2009).

Climate resilience can also be enhanced through the application of biofertilisers like *Azolla* and the use of salt-tolerant rice varieties. In contrast, the continued reliance on high-input farming marked by excessive use of chemical fertilisers and pesticides has led to soil degradation and reduced biodiversity. These practices compromise soil physical, chemical, and biological properties, ultimately hindering plant growth (Lal, 2015).

Furthermore, unreliable irrigation due to infrastructure damage or water shortages remains a critical challenge. Adjusting planting schedules has proven to be a practical strategy; studies show yield increases of up to 7.8% during the rainy season and 5.6% during the dry season (Tuong *et al*., 2005). This adaptive measure not only stabilizes harvests but also reduces dependency on irrigation and enhances water use efficiency.

Analyses of the *Salibu* System

The *Salibu* system is a rice cultivation technique that utilizes the plant's natural ability to regenerate. After the main harvest, the plants are not immediately uprooted but are left to regrow from the remaining stems (stubble) that are cut precisely. Interestingly, the term *"Salibu"* originates from the Minangkabau dialect in West Sumatra, meaning *"once planted, can be harvested many times"*, as illustrated in Fig. 1.

Unlike traditional systems that require farmers to replant each season, this method allows for one to two additional harvests without the need to resow seeds. Research has shown that the double-cutting technique in the *Salibu* system can reduce the need for seeds and labour, while still producing around 6–7 tons of grain per hectare over six consecutive harvests (Shiraki *et al*., 2020).

Initially developed by farmers in Solok Regency, West Sumatra, in the early 2000s, the system was based on observations that rice plants harvested at the right age could produce productive new shoots. After receiving support from the Department of Agriculture and the Agricultural Technology Assessment Institute, it began to be introduced in other provinces such as North Sumatra, West Java and West Nusa Tenggara (Fitri *et al*., 2019).

Cropping systems that include ratooning improve energy efficiency and reduce both greenhouse gas emissions and production costs by 32–42% (Yuan *et al*., 2019). When agronomic practices are well-managed, the ratoon crop can be produced with just 50% of the labour and resources, while yielding about 60% of the main crop (Alekhya *et al*., 2024). Additionally, this system significantly reduces production costs while saving time, water, and seeds (Zipporah *et al*., 2023).

Excess soil moisture, especially from stagnant water, can prevent shoot development and lower yields. This is commonly seen in rainfed fields or water-saving systems where moisture availability fluctuates (Deshabandu *et al*., 2024). Drought, plant lodging, and post-harvest mismanagement may also reduce the success of regrowth (Shiraki *et al*., 2020). A brief comparison of the *Salibu* and conventional planting systems is shown in Table 1.

Innovation in the *Salibu* System for Lowland Rice

Current innovations in applying the *Salibu* system in lowland rice focus on improving basic agronomic practices, especially stem cutting techniques and the timing of early regrowth. These factors are crucial for maximising shoot regeneration and yield. Research shows that an optimal cutting

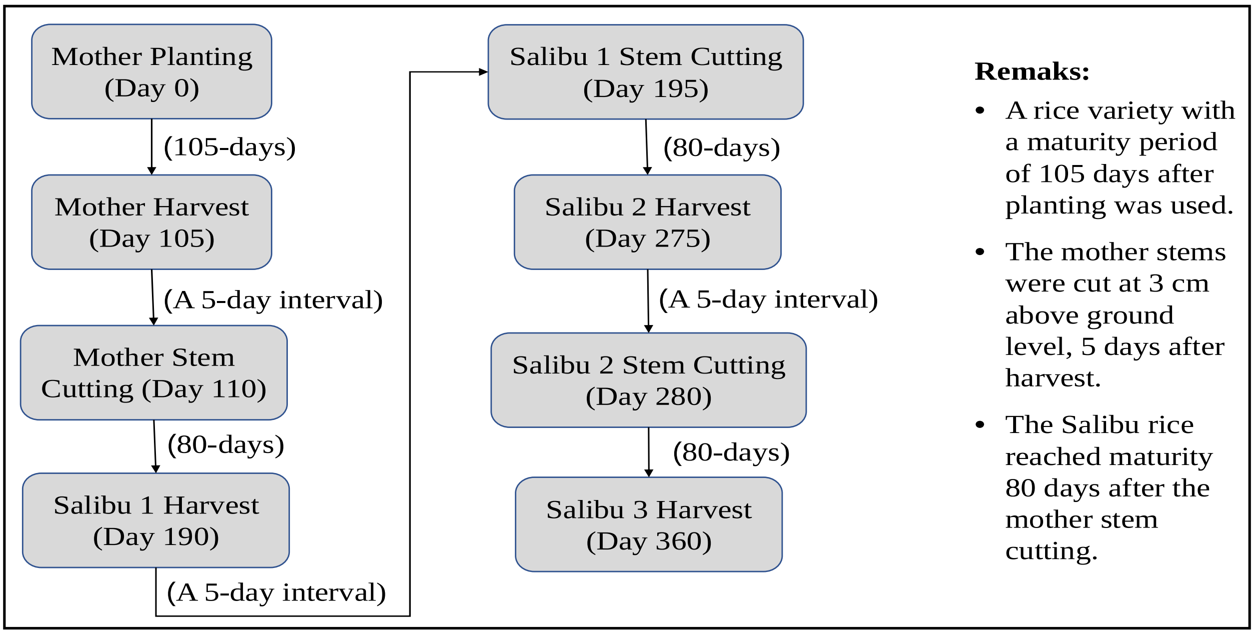

Fig. 1. Flow diagram of the *Salibu* system in lowland rice (one-year cycle).

Table 1. Salibu vs. conventional planting system (lowland rice)

No.	Aspect	Conventional System	Salibu System
1.	Plant source	New seeds	Shoots from cut stubble
2.	Seed use	High	Low
3.	Land preparation	Repeated each season	Once only
4.	Planting method	Transplanting each time	No replanting after main crop
5.	Labor requirement	High	Lower
6.	Growth duration	±105–115 days	105 days (main), 80 days (Salibu)
7.	Harvest frequency	1–2 times/year	Up to 4 times/year
8.	Yield trend	Stable	Gradually decreasing
9.	Fertilizer need	Full dose every season	Reduced, adjusted
10.	Cost efficiency	Low	High
11.	Soil disturbance	Frequent	Minimal
12.	Water requirement	Seasonal irrigation	Continuous irrigation needed
13.	Environmental impact	Higher	Lower
14.	Residue management	Often discarded	Used for regrowth
15.	Best land suitability	All lowland types	Irrigated lowlands

height of 20–25 cm above the soil surface preserves active lower stem nodes capable of producing new tillers (Dobermann and Fairhurst, 2000). Cutting too high reduces regenerative efficiency, while cutting too low may damage the plant's growing point. Although efficacy depends on soil moisture, the double-cutting technique, first at 20–40 cm, then at 5 cm, has been shown to improve grain yield (Shiraki *et al*., 2020).

Increased plant height, number of productive tillers, and grain yield have been reported with 10 cm cutting combined with the application of Seprint liquid organic fertiliser (Alridiwirsah *et al*., 2021). Planting time is also a key factor. Depending on the variety, the first harvest should occur between 105 and 110 days after planting or when grains reach physiological maturity. Ensuring that the remaining stem tissues are still physiologically active supports rapid shoot regeneration (Abdulrachman *et al*., 2015). Although lower cutting heights (*e.g*., 3 cm) may delay the generative phase, they can improve yield components and ratoon yield. Cutting at 10–15 cm promotes better shoot development than at 20–25 cm (Setiawan *et al*., 2014).

The AWD irrigation technique, which maintains ideal soil moisture without prolonged flooding, has revolutionised water management practices. AWD enhances root and shoot development and increases water-use efficiency by up to 30% (Bouman *et al*., 2007). It also improves phosphorus availability and raises yields, increasing water efficiency by up to 35% compared to continuous flooding (Xu *et al*., 2020). Additionally, AWD increases soil macro-porosity by 46% and pore connectivity by 20%, enabling more effective root water uptake (Islam *et al*., 2024). Maintaining a water depth of 5–10 cm has also been shown to reduce water usage by up to 45% without negatively impacting yield or income (Atwill *et al*., 2023).

The integration of environmentally friendly inputs is another critical component in developing the *Salibu* system. Organic and biological fertilisers increase nutrient availability and plant resistance to soil-borne pathogens. Biofertilisers such as *Azospirillum*, *Rhizobium*, and *Trichoderma* significantly stimulate tiller growth (Mthiyane *et al*., 2024). The combination of *Trichoderma* and *Aspergillus* has been found to improve plant height, panicle number, and 100-grain weight, while reducing disease symptoms by up to 64.7% (Sutarman *et al*., 2023). *Trichoderma*-based biofertilisers have further been shown to enhance photosynthesis rate, chlorophyll content, tiller number, and grain weight by up to 30% compared to untreated controls (Doni *et al*., 2018).

Selecting high-performing cultivars compatible with the *Salibu* system is essential. Varieties like Ciherang, Inpari 32, and Mekongga have strong regenerative traits, such as vigorous tillering, sturdy stems, and good response to re-fertilisation. Research is increasingly focused on breeding for regenerative rice systems with improved yield components. Inpari 42 responds well to 300 kg/ha of NPK, while Inpari 32 performs effectively in the Jajar Legowo system, which enhances light and air penetration (Khairullah *et al*., 2021).

Several mechanization have been introduced to improve efficiency in *Salibu* implementation. One major challenge is achieving accurate and consistent stem cutting, which is labour-intensive if done manually. To address this, portable motorised stem cutters have been developed, enabling precise cutting at the ideal height (Dixit *et al*., 2022). The use of double-blade headers during harvest also supports accurate cutting and grain preservation, both essential for healthy ratoon growth (Huang *et al*., 2020). Recent innovations in mechanical harvesting tools, including energy-efficient stem cutters, have further supported the success of the first ratoon period (Fu *et al*., 2022).

In terms of irrigation, micro-irrigation systems such as small channels and micro-sprinklers have been introduced to ensure uniform soil moisture, especially in poorly drained areas. These systems facilitate more practical AWD applications (Tuong *et al*., 2005). Micro-sprinklers with an evapotranspiration rate (ETc) of 1.25 have been shown to increase plant height, biomass, leaf area, and grain yield, while improving water use efficiency. In just 1–2 hours, with a discharge of 91 L/hour, they can distribute moisture up to 3 meters, achieving 76–100% field capacity (Arulkar *et al*., 2008).

Impact of *Salibu* System on Lowland Rice Productivity

One of the main advantages of the *Salibu* system is its ability to maintain competitive yields compared to conventional replanting methods. Numerous studies have shown that *Salibu* yields can reach 80–95% of the main harvest, depending on the rice variety, agronomic practices, and environmental conditions (Yamaoka *et al*., 2023). Notably, the double-cutting technique used in this system has achieved yields of 6–7 tons/ha across six consecutive cropping cycles, comparable to initial planting yields and indicative of high production efficiency (Oda *et al*., 2020; Shiraki *et al*., 2020). Additionally, *Salibu* increases straw production, which plays a key role in stimulating tillering and enhancing nutrient cycling (Oda *et al*., 2020).

The performance of the *Salibu* system depends heavily on several critical factors, including cutting height, soil moisture levels, and harvesting time (Awalina *et al*., 2021). With proper stem cutting, supplemental fertilisation, and AWD irrigation, the *Salibu* system can maintain stable productivity. Compared to conventional replanting, it enables two harvests within 180–200 days, and with optimal water management and double-cutting, yields can increase by up to 69% (Shiraki *et al*., 2020). These findings affirm that *Salibu* is a viable and efficient method to sustain rice production amid climate challenges (Yamaoka *et al*., 2023; Hong and Huang, 2024).

The *Salibu* system significantly reduces input requirements. By eliminating the need for land tillage, seed preparation, and transplanting, farmers can save 30–40% on labour costs (Paman *et al*., 2014; Fitri *et al*., 2019). By regenerating from existing stubble, the *Salibu* system reduces seed use by nearly 100% and improves labour and seed efficiency by 29% and 52% compared to double replanting (Shiraki *et al*., 2020). By enabling multiple harvests from a single planting, *Salibu* saves time, water, seed, and labour (Fitri *et al*., 2019). Furthermore, moderate AWD irrigation can reduce methane (CH_4) emissions by 45–90% and irrigation water use by up to 23% without compromising yield (Ishfaq *et al*., 2020). The AWD can reduce greenhouse gas emissions and global warming potential by up to 73%, with minimal yield loss, depending on the drying cycle's intensity and duration (Gao *et al*., 2024). In Arkansas, USA, AWD even improved nitrogen uptake and increased rice yields by up to 11% compared to continuous flooding (Atwill *et al*., 2020).

Environmental efficiency in the *Salibu* system is also supported by the use of organic and microbial fertilisers. Biofertilisers such as *Azospirillum* and *Trichoderma* enhance plant resilience to drought and improve nutrient absorption (Lal, 2015). *Azospirillum* inoculation significantly improves rice growth and yield, offering a sustainable alternative to synthetic nitrogen fertilisers. *Trichoderma*-based biofertilisers can increase yields by up to 30% and reduce the harmful effects of excessive chemical use (Razie and Anas, 2008).

From an economic perspective, the *Salibu* system can increase farmers' profits by up to IDR 4.5 million per hectare per season through savings in labour, seed, and land preparation (Abdulrachman *et al*., 2015). Additionally, the revenue-to-cost (R/C) and

Benefit-cost (B/C) ratios of *Salibu* are higher than those of conventional systems, indicating greater farming feasibility (Fitri *et al*., 2019). With two or more harvests per year and reduced risk of crop failure, especially in climate-vulnerable regions, *Salibu* contributes to household food security and income stability (Wassmann *et al*., 2009). Some studies even report up to four harvests from a single planting within a year, an impressive feat in the context of intensified agriculture (Sakti *et al*., 2021).

From a social perspective, increased productivity from the *Salibu* system boosts local labour participation in key tasks like pruning, fertilising, and irrigation. It also encourages resource-efficient farming, reduces reliance on external inputs, and strengthens community resilience. In Percut Sei Tuan District, *Salibu* improved farmer incomes, prevented land conversion, and empowered farmers to produce organic pesticides and bokashi compost, supporting sustainable agriculture (Mayly and Syafri, 2018).

Overall, the *Salibu* system can reduce water usage by up to 60%, lower labour requirements by up to 50%, and significantly cut production costs all without reducing yields (Paiman *et al*., 2022). From economic, environmental, and social perspectives, *Salibu* represents an agricultural innovation that is efficient, profitable, climate-resilient, and farmer-friendly.

Adoption and Dissemination of *Salibu* System in Lowland Rice

The successful adoption of the *Salibu* system depends on social, technical, and institutional factors, especially farmers' skills in post-harvest fertilisation, water management, and precise stubble cutting. Without proper knowledge and training, many farmers fail to regenerate tillers effectively, causing discouragement and abandonment of the practice (Mayly and Syafri, 2018; Effendy *et al*., 2021; Paiman *et al*., 2022). Thus, technical competencies, effective communication, and institutional support form the foundation for the effective and sustainable implementation of the *Salibu* system.

To achieve the intended outcomes, key agronomic practices such as maintaining optimal cutting height and implementing consistent water management, especially through techniques like AWD, must be consistently applied (Yamaoka *et al*., 2023). The lack of structured technical assistance in many regions often blocks successful implementation. Additionally, the *Salibu* system performs best on sandy loam soils with good water supply and drainage, while heavy clay or poorly drained soils hinder shoot regeneration and overall performance (Shiraki *et al*., 2020). Nonetheless, with appropriate water management, this method has also demonstrated improvements in soil porosity and organic carbon content, benefiting tiller growth even in marginal environments such as type C tidal lands (Sakti *et al*., 2021).

Institutional support, particularly from pioneer farmers and agricultural extension officers, serves as a key driver of *Salibu* adoption. Farmers who have successfully implemented the system often become role models through demonstration plots or Farmer Field Schools (FFS), both of which are highly effective platforms for disseminating agricultural innovations at the local level (Mapiye *et al*., 2021; Yitayew *et al*., 2021). Through the participatory learning approach employed in FFS, farmers' capacity and confidence to implement new techniques increase significantly (Ilar, 2015).

Solok Regency in West Sumatra, the birthplace of the *Salibu* system, serves as a model for its development and dissemination. Since the early 2000s, collaboration between the Agricultural Technology Institute and local authorities has supported technical assistance and innovation, with pioneer farmers developing site-specific fertilisation and cutting techniques (Abdulrachman *et al*., 2015). Consequently, rice productivity in this region increased by approximately 35%, with yields reaching 4.5–5.0 tons/ha without requiring replanting each season (Shiraki *et al*., 2020; Sakti *et al*., 2021).

Challenges and Limitations of *Salibu* System

Despite its potential, the *Salibu* system faces biophysical and socio-institutional challenges. A key limitation is varietal suitability, as not all rice cultivars regenerate well after stubble cutting. Early-maturing varieties like Ciherang and Inpari 32 are compatible, while late-maturing or softstemmed cultivars often underperform (Khaerana *et al*., 2023).

Soil characteristics, including stable moisture, good drainage, and moderate texture, are crucial for *Salibu* success, while overly dry or waterlogged soils hinder tiller regeneration and increase stress vulnerability (Shiraki *et al*., 2020; Agustina *et al*., 2022). Moreover, untimely stubble cutting and poor field sanitation practices can elevate the risk of pest and disease outbreaks, such as bacterial leaf blight (*Xanthomonas oryzae*) and brown spot (*Rhizoctonia solani*) (Khaerana *et al*., 2023).

A major technical challenge is the limited knowledge and training of both farmers and extension workers. Many lack understanding of shoot regeneration, pruning, and water management, while extension agents often have no formal *Salibu* training, causing inconsistent adoption and results (Abdulrachman *et al*., 2015). The impact of climate change, particularly shifts in pest and disease dynamics, further complicates management, underscoring the need for integrated pest surveillance and predictive modelling to support adaptive, ecosystem-based control strategies (Subedi *et al*., 2023).

In addition, more research is needed to develop or identify rice varieties that are better adapted to rainfed lowland ecosystems, which are inherently more vulnerable to water stress and soil degradation (Erythrina *et al*., 2021; Zarwazi *et al*., 2022). Without adequate investments in varietal development, structured capacity-building programs, and sustained technical support, the broader scalability of the *Salibu* system across diverse agroecosystems remains constrained.

From a socio-economic perspective, adoption of the *Salibu* system has largely been driven by smallholder pioneers operating at the community level. However, resistance to change remains high, particularly in areas with strong traditions of conventional replanting using certified hybrid seeds. Scepticism about ratoon yield performance and a lack of locally visible success stories continue to hinder broader acceptance (Yamaoka *et al*., 2023).

Future Development Directions and Recommendations

- The sustainable development of the *Salibu* system requires a comprehensive, interdisciplinary research and policy approach. Key priorities include adapting *Salibu* practices and rice cultivars to Indonesia's diverse lowland agroecosystems, with site-specific management of soil water, cutting height, and fertilisation timing (Paiman *et al*., 2022).
- The system has demonstrated adaptability to elevated temperature conditions, as evidenced by its successful application in Central Java, highlighting its potential for climate-resilient rice production (Oda *et al*., 2020). However, yield outcomes remain variable across regions; in some locations, *Salibu* yields still lag behind those of conventional replanting systems (Sakti *et al*., 2021; Yamaoka *et al*., 2023).
- Future research should investigate the long-term environmental impacts of *Salibu*, including greenhouse gas emissions, soil quality, and water-use efficiency. Using life cycle assessment (LCA) frameworks is essential for evaluating its sustainability, with initial Solok studies showing reduced pollution and emissions alongside improved environmental performance (Aswin *et al*., 2023; Qiao *et al*., 2024).
- Effective scaling of the *Salibu* system requires context-specific, evidence-based extension using practical materials like visual guides, mobile videos, and hands-on training to empower farmers and workers (Mayly and Syafri, 2018). Combining local wisdom with scientific agronomy enhances knowledge retention and practical application, especially when supported by participatory learning models (Limpo *et al*., 2022).
- Digital platforms like WhatsApp and Facebook aid peer-to-peer learning but have limited reach in low digital literacy areas. Thus, hybrid strategies combining ICT and traditional outreach are recommended (Agnese *et al*., 2024). Participation in digital farming communities has been positively correlated with increased productivity and improved decision-making

(Elkassim *et al.*, 2024; Mendes *et al.*, 2024). In this regard, involving lead farmers as local mentors and organising farmer groups or cooperatives can accelerate innovation diffusion at the grassroots level.

- To broaden its application, the *Salibu* system must be strategically integrated into national agricultural development programs, such as the Food Estate initiative and the IP400 intensification program. *Salibu* aligns well with IP400's goal of achieving four rice harvests per year, as it enables two harvests from a single planting, thereby saving labour, water, and time (Mayly and Syafri, 2018; Yusup and Sonia, 2024).

CONCLUSION

This review highlights the *Salibu* system as a sustainable alternative to conventional rice replanting in Indonesia's lowland agroecosystems. By using the rice plant's natural regenerative ability, *Salibu* allows multiple harvests from a single planting, reducing seed, labour, and water use while maintaining competitive yields. Agronomic innovations like stem cutting, AWD irrigation, and biofertilisers improve efficiency and adaptability. However, adoption is limited by unsuitable rice varieties, soil variability, low farmer technical skills, and weak institutional support. Successful implementation depends on targeted training, participatory extension, and supportive policies. Integrating *Salibu* into national strategies and climate-resilient programs can expand its impact. Overall, the system offers great potential to boost productivity, reduce environmental impact, and support smallholders, but requires coordinated efforts in research, policy, and on-farm practice to realise this promise.

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